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PRINCIPAL INVESTIGATOR: Ann E. Grow

CONTRACTING ORGANIZATION: Biopraxis, Incorporated
San Diego, California 92191-0078

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Ann E. Grow

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Biopraxis, Incorporated
San Diego, California 92191-007

E-Mail: agrow@biopraxis.com

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13. ABSTRACT (Maximum 200 Words)

Biopraxis is developing a method for production of novel catalysts from inexpensive precursors, at high yield, under mild conditions. Under an earlier program, Biopraxis demonstrated that catalysts produced by this method can effectively neutralize the agent simulants diisopropyl fluorophosphate (DFP) and 2-chloroethyl ethyl sulfide (CEES). Government testing identified a formulation that exhibited excellent efficacy against both GD and HD, reducing nerve agent penetration by 93.1% and mustard penetration by 81.5% in comparison with the non-reactive TSP. Accordingly, the Government awarded a follow-on program. The program was cut short due to funds being diverted for the Iraq war. The best formulation that had been identified by that time did not allow any detectable GD penetration in 20hours (99.96% reduction) and was projected to take more than 950 hours to reach breakthrough (a 16,502% increase). This same formulation also showed excellent efficacy against HD; i.e., a 217% increase in the time to breakthrough, and a 59% reduction in penetration by 20hours, in comparison with the non-reactive TSP. Since the catalysts are solid particulates, formulations may contain mixtures of catalysts that are superior for decontaminating different agents.

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INTRODUCTION

Biopraxis is developing a method for production of novel catalysts from inexpensive precursors, at high yield, under mild conditions. Under the first "reactive Topical Skin Protectant (rTSP)" program, Biopraxis demonstrated that catalysts produced by this method can effectively neutralize chemical warfare agents. Catalysts were prepared and screened against the vapors of the chemical warfare (CW) simulants diisopropyl fluorophosphate (DFP) and 2-chloroethyl ethyl sulfide (CEES) in simple vial tests. More than three dozen catalysts were found to be effective at degrading the simulants. Select catalysts that performed well against one or both of the simulants were then prepared as formulations comprising the catalyst mixed with the non-reactive Topical Skin Protectant (TSP) oil, thickener, and (for moist catalyst preparations) surfactant; and then tested against a DFP vapor challenge using a modification of the penetration cell protocol developed by USAMRICD. Of the 22 catalysts screened in formulations, at least 18 appeared promising for protection against DFP. Gas chromatographic analyses of the vapors penetrating the rTSP formulations confirmed that the different catalysts produced a range of different reaction products.

Formulations submitted to the Government for testing against GD exhibited superior efficacy in comparison with the non-reactive TSP (I3004). The Government subsequently placed a purchase order to acquire batches of several catalysts for more extensive Government testing. The most promising formulation (I3600) that had been identified by early July 2001 showed substantially superior efficacy against both HD and GD. While I3004 reached GD breakthrough (time to 1,000 ng total penetration) at 346±68 min and allowed 6,672±865 ng to penetrate over 20 hr, I3600 did not reach breakthrough until 2,086±1349 min and allowed only 461±648 ng to penetrate by 20 hr. While I3004 reached HD breakthrough at 586±46 min, and allowed 2,758±299 ng to penetrate over 20 hr, I3600 did not reach breakthrough until 1,704±548 min and allowed only 510±368 ng penetration by 20 hr.

Accordingly, the Government awarded a follow-on rTSP program. Under this second program, Biopraxis proposed to test additional novel catalysts against CW agent simulants, characterize the catalysts, and provide select samples for Government testing.

BODY

The catalysts studied on this USAMRICD program were originally developed for use in treating environmental pollutants. Biopraxis proposed to use data on pollutant treatment efficacy, coupled with tests of select catalysts against CW agent simulants, to identify promising catalysts for Government formulation tests with surety materiel.

Catalyst Selection

Biopraxis catalogues all catalysts and their properties in an extensive database. This database contains all data collected during the first rTSP project and Government surety materiel test results, as well as data on environmental remediation. At the beginning of the follow-on rTSP program, the database was re-analyzed in an effort to determine what production parameters might yield catalysts that are effective against CW agents.

Catalysts have been produced under both oxygen and nitrogen environments. Analysis of the database suggested that oxygen-based techniques might hold great promise for production of catalysts for degrading CW agents, particularly from the perspective of future production-scale efforts, in that production costs are expected to be even lower than for catalysts produced under nitrogen. In addition, catalysts produced under oxygen are less likely to be oxidized when exposed to the atmosphere than those produced under nitrogen, and the resulting skin cream therefore easier to produce, package, and store. However, little work had been done on these catalysts under the

earlier rTSP work. Of the ten catalysts sent for Government GD/HD testing under the purchase order, only two were produced under oxygen. One of these (TFO01/F_S) performed well against both GD and HD, and another (TMO01/M) performed exceptionally well against GD. In addition, several catalysts produced under oxygen had performed well against DFP in vial or flow cell tests at Biopraxis, but had not yet been tested in Government GD/HD tests.

On the environmental remediation studies, Biopraxis had identified two other production parameters that can significantly impact the properties of the catalyst. The available data suggested there may have been similar phenomena occurring with catalysts in the rTSP program. Because experiments with agent simulants had not been specifically designed to address the impact of these parameters, the data were often scattered and incomplete. However, in some cases, the production parameters that produced catalysts that were more effective in DFP and CEES vapor test results were the same as those that produced superior catalysts against environmental pollutants.

Accordingly, most of the work on the current rTSP program concentrated on catalysts produced under oxygen; and explored the impact of the other production parameters on simulant treatment efficacy, using the production methods developed elsewhere. During catalyst production, two alternatives for each of the two key production parameters were used, resulting in a matrix of four 'recipes' for each type of catalyst. Three catalysts were chosen for use in studies to evaluate the impact of tailoring these production parameters, i.e.:

- TFO01/F_S – This catalyst performed very well against GD (81.3% reduction in agent penetration over 20 hours' exposure to vapor, in comparison with I3004) and moderately well against HD (56.4% reduction) in Government testing after the initial Biopraxis rTSP program; and also performed well against DFP and CEES in Biopraxis vial tests during the initial rTSP program. Production parameter alternatives were "F" vs "F_M" and "C" vs "D".

- TMO01/M – This catalyst performed very well against GD (83.8% reduction) and moderately well against HD (41.9% reduction) in Government testing after the initial Biopraxis rTSP program; and performed well against DFP in vial tests and flow cells at Biopraxis. Production parameter alternatives were "M" vs "M_F" and "G" vs "C".

- MMO01/M – This catalyst did well against DFP in vial tests and Reifenrath formulation tests at Biopraxis, but performed only moderately well in Government tests against GD (10.9% reduction, using a formulation prepared by Biopraxis on the initial rTSP program). Production parameter alternatives were "M" vs "M_F" and "G" vs "C".

The initial production run was done on a small (100 mL) scale, to produce enough material for in-house vial tests against DFP and CEES. The most effective catalysts were then to be produced on a larger (2 L) scale to provide samples for Government testing (see below).

Surprisingly, the MMO01/MG recipe did not produce any catalyst. This may have been due to some sort of contamination, or possibly an inadvertent failure to include all of the necessary ingredients. It was also disappointing, since the combination of M and G was highly effective at producing catalysts in the TMO01 matrix; i.e., high percentages of both DFP and cEES were removed / destroyed during simulant testing. The other recipes produced the expected yield of catalyst, and were characterized and screened against simulants.

Catalyst Characterization

Studies on environmental remediation had found, surprisingly, that a single production run could yield more than one type of particle (e.g., the particles were visibly different from each other when examined under the microscope), and that the different particles in a single run have different catalytic properties. Therefore, the efficacy of the rTSP formulation might be optimized by

maximizing the proportion of a given type of particle incorporated into the skin cream. This could be accomplished by developing methods for separating the particle types after production and only incorporating the most active particles into the rTSP. Alternatively, production of a particular particle-type might be maximized by altering the production parameters. (Preliminary studies on environmental remediation indicate the latter alternative may indeed be feasible.) In addition, future catalyst bulk-scale production will require analytical methods to assess catalyst quality.

Therefore, the catalysts were subjected to a series of analyses, using techniques that enabled data to be collected from individual particles in mixtures (e.g., light microscopy, Raman microscopy, scanning electron microscopy, etc.) These analyses reveal information on the proprietary nature of the catalysts, and are not included in this report.

Catalyst Testing with Simulants

The catalysts are produced in water and are highly porous (i.e., each particle contains an exceptionally large reservoir of water.) Earlier studies indicated that they could be freeze-dried and still exhibit catalytic activity (although in some instances, the range of environmental pollutants against which they were effective was altered.) Dried catalysts were easier to screen against simulants, since water vapor could have an affect in and of itself (e.g., hydrolyze the CEES). Accordingly, freeze-dried catalysts were tested for efficacy against DFP and CEES in simple vial tests. 3.0 ± 0.1 mg catalyst was placed into a 10 mL gas-tight, PTFE/silicon septum vial, along with either 2.5 µL of CEES or 2.0 µL DFP on a cellulose paper filter, and incubated at 20°C for 24 hr. Standards ranged from 0.1 - 2.0 µL DFP, or 0.1 - 2.5µL CEES, on cellulose paper filters. Samples, catalyst-only controls, and standards were all run in triplicate. After incubation, a 10 cc gas-tight syringe was used to pull a 1 mL vapor sample from each vial, and the vapor was injected directly into the GC. The syringe was flushed with compressed air between injections. Analyses were done on a Buck Scientific 910 GC equipped with an Alltech AT-5 (30m) column, and flame ionization (FID), photoionization (PID), and dry electrolytic conductivity (DELCD) detectors. The DELCD is sensitive to halogenated compounds, while the PID is sensitive to unsaturated compounds. The FID hydrogen gas was set at a flow rate of 25 mL/min. Both the FID and PID were run at 150°C, and the DELCD at 1200°C. The chromatographic grade helium carrier gas was set at 6 psi. The column-oven temperature was ramped from 40°C to 170°C over 10 min when analyzing DFP, and from 40°C to 200°C over 10 min when analyzing CEES.

In most cases, the production parameters had a significant impact on catalyst efficacy against DFP and CEES (Table 1.) The pattern of these effects was often similar for the two simulants; i.e., catalysts that were effective against DFP also tended to be effective against CEES.

For the TMO01 matrix, the most effective catalyst against both DFP and CEES was produced when M and G were the key production parameters. This combination produced a catalyst that removed and/or destroyed 653.0 ± 27.5 mg DFP / g catalyst, representing 92.3 ± 0.5% of the DFP added to the vial (Figure 1). This same catalyst removed and/or destroyed 594.7 ± 100.0 mg CEES / g catalyst, representing 83.0±12.5% of the CEES added to the vial (Figure 2). It was interesting to note the trends in efficacy for this catalyst against DFP. With either M or M_F, catalysts produced with G outperformed those produced with C; and with either G or C, those produced with M outperformed those produced with M_F. Although such definite matrix patterns were not seen in the results for CEES, the catalyst that performed best against DFP also exhibited superior efficacy against CEES.

The results of this matrix was particularly interesting, since TMO01/MC was the recipe used to prepare the catalyst that performed very well against GD (ICD3554 yielded an 83.8% reduction in GD penetration) and moderately well against HD (41.9% reduction) in earlier Government tests. If simulant vial testing could be used to predict formulation efficacy against surety material, the new TMO01/MG recipe should yield a catalyst with superior performance against both chemical

warfare agents.

Table 1. Results of Simulant Tests with Freeze-Dried Catalysts (Italics indicate recipes previously tested by the Government)

Catalyst	*% DFP removed/ destroyed*	*% CEES removed/ destroyed*
TFO01/FC	98.5 ± 2.5%	84.5 ± 14.0%
TFO01/FD	29.9 ± 51.8%	57.2 ± 38.3%
TFO01/F_MC	33.3 ± 57.6%	51.1 ± 26.4%
TFO01/F_MD	52.9 ± 50.2%	77.4 ± 25.1%
TMO01/MG	92.3 ± 0.5%	83.0 ± 12.5%
TMO01/MC	74.0 ± 9.0%	20.8 ± 36.0%
TMO01/M_FG	84.4 ± 6.3%	65.1 ± 15.2%
TMO01/M_FC	65.1 ± 0.6%	66.8 ± 45.1%
MMO01/MC	44.1 ± 45.1%	47.7 ± 24.1%
MMO01/M_FG	39.2 ± 36.5%	45.5 ± 28.9%
MMO01/M_FC	28.5 ± 27.1%	19.1 ± 10.6%
MSR03/FL	99.9 ± 0.05%	
MSR03/MF	52.8 ± 6.9%	
MSR03/ML	27.3 ± 62.8%	
MSR06/ML	85.0 ± 21.2%	
MSR06/FL	80.1 ± 22.6%	

The vial test results for TFO01 showed the most effective catalyst against DFP and CEES was produced with F and C as the key production parameters. The resulting catalyst removed/destroyed 688.8 ± 24.4 mg DFP / g catalyst (98.5 ± 2.5% DFP removed/destroyed; Figure 3). This was one of the few vial tests in which breakdown products could be detected. This same catalyst was also the most effective against CEES, removing/destroying 569.5 ± 65.3 mg CEES / g catalyst (85.4 ± 14.0% CEES removed/destroyed; Figure 4). When comparing Figures 3 and 4, it was apparent that although the exact ratios are different, the overall trends within the matrices were similar for DFP and CEES.

A variation on the TFO01/FD recipe was used to prepare the TFO01/F_S catalyst that was effective against both GD (81.3% reduction) and HD (56.4% reduction) in earlier Government penetration cell tests. TFO01/F_S removed/destroyed 83% of the DFP and ≥ 66% of the CEES in earlier vial tests. If the simulant vial test results could be used to predict surety material formulation results, TFO01/FC might provide even better performance against CW agents.

Overall, MMO01 catalysts performed only moderately well compared to those in the TMO01 and

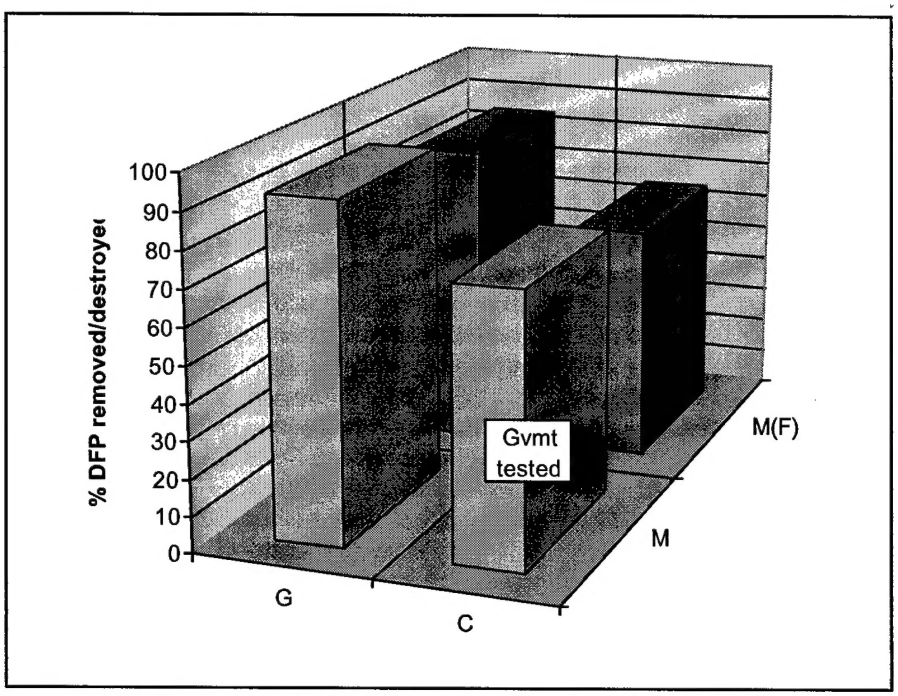

Figure 1: TMO01 vial tests against DFP

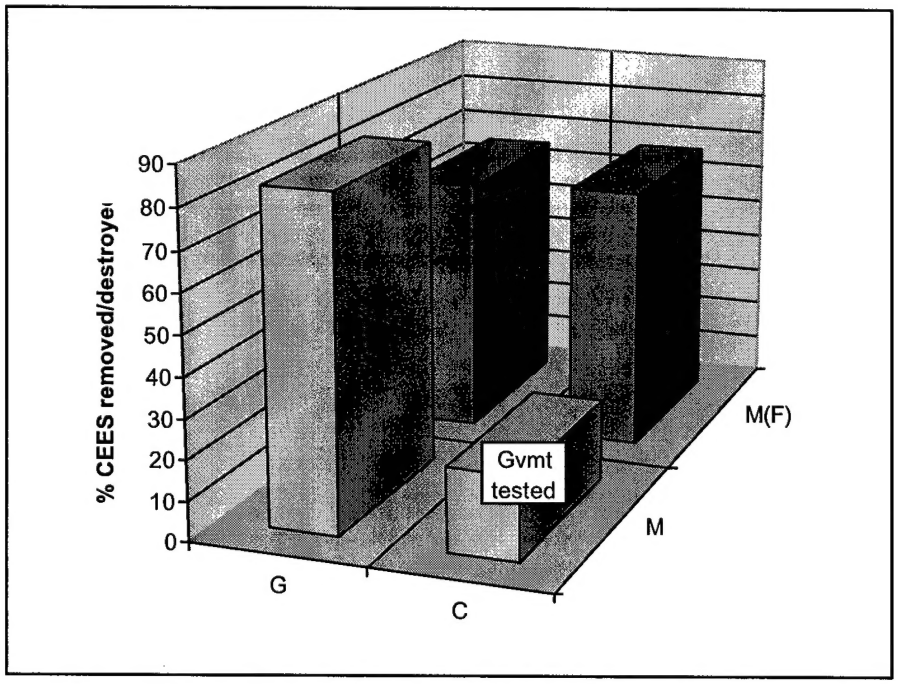

Figure 2: TMO01 vial tests against CEES

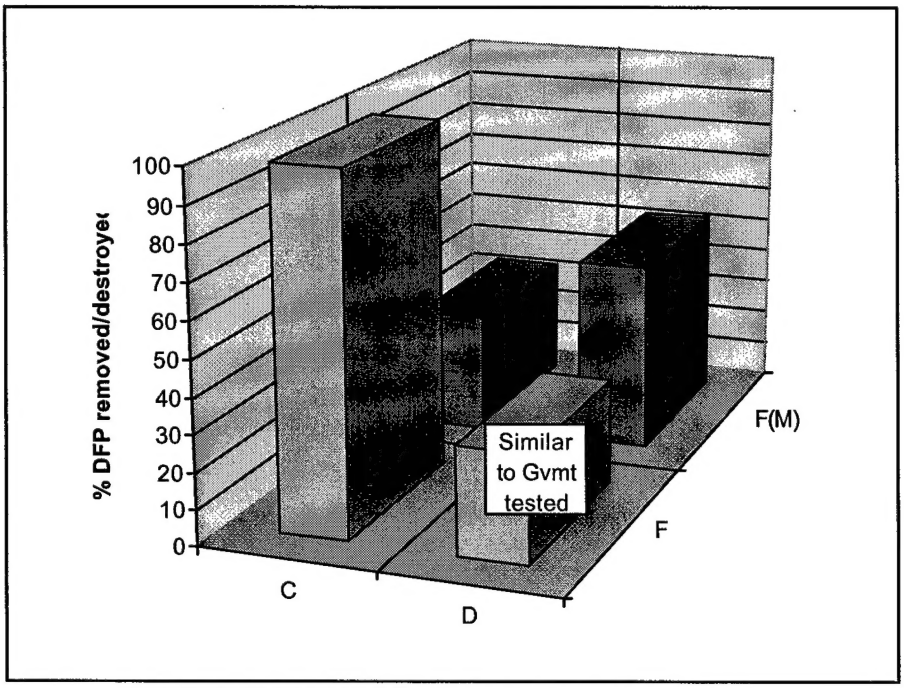

Figure 3: TFO01 vial tests against DFP

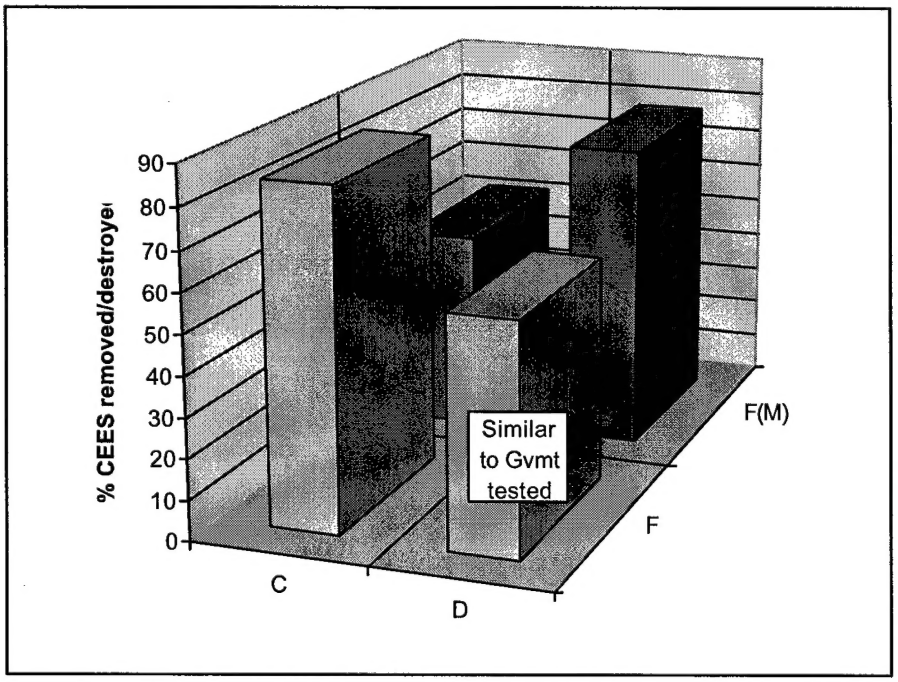

Figure 4: TFO01 vial tests against CEES

TFO01 matrices. The most effective MMO01 catalyst removed/destroyed 292.2 ± 289.7 mg DFP / g catalyst, or 44.1 ± 45.1% of the DFP placed in the vial (Figure 5). This same catalyst removed/ destroyed 333.6 ± 171.7 mg CEES / g catalyst, or 47.7± 24.1% of the CEES in the vial (Figure 6). However, like the other catalyst matrices, MMO01 catalysts also exhibited similar patterns in efficacy against DFP and CEES (compare Figures 5 and 6), with the exception that, as noted above, the combination of M and G did not produce any catalyst at all. This was an unexpected result, since the MMO01/MG recipe is very similar to the MMO01/MC recipe; and since switching from the TMO01/MC to the TMO01/MG recipe not only produced a catalyst, but yielded a superior one.

The MMO01/MC recipe was used to prepare the formulation that yielded 10.9% GD reduction in earlier Government tests (ICD3361). Since tailoring the MMO01 recipe did not appear to have produced a more effective catalyst, the MMO01 series was dropped from the Government test program.

In order to provide as many samples to the Government for testing as possible, the simulant test matrix with the MSR03 and MSR06 catalyst series against DFP was incomplete, and studies were not done with CEES. MSR03/FL performed moderately well in earlier Government tests (65.3% reduction in GD penetration, and 53.2% reduction in HD penetration.) Substituting M for F, and substituting F for L, can produce superior and/or very unusual catalysts. DFP tests, however, indicated that the original 'recipe' produced the best catalyst, with essentially all DFP removed / destroyed during the test period, whereas MSR03/MF and MSR03/ML did not do nearly as well (52.8 and 27.3 % DFP removed / destroyed, respectively.) MSR06/FL performed extremely well in earlier Government tests (93.1% reduction of GD penetration, and 81.5% reduction of HD penetration); and environmental remediation studies found that substituting M for F could produce a catalyst that is superior for other applications. MSR06/ML may have performed marginally better against DFP, although the difference was not statistically significant.

Catalyst Selection and Production for Government Testing

Three catalysts were used in earlier Government weanling pig tests, in formulations ICD3603 (based on TFO01/F_S), ICD3553 (based on TSR06/M), and ICD3600 (based on MSR06/F). Despite very promising penetration cell tests, none of these formulations appeared to be effective in the weanling pig tests.

The formulations used in the weanling pig tests were prepared under air and stored under air for as long as nine months. It is highly likely that the catalysts were oxidized during the prolonged storage under adverse conditions. Biopraxis requested that the Government (a) retest the air-stored formulations by the Reifenrath protocol, to confirm that their efficacy was degraded, and then (b) conduct new animal tests using freshly-prepared formulations, if the penetration cell tests indicate that the stored formulations are no longer effective. The Government testing was halted, due to lack of funds (monies were diverted to support the war in Iraq) before this could be done.

It should be noted that analysis of the results from Government surety tests should take into account when the Government prepared the formulation, whether it was prepared under air, and how long it was stored (and under what conditions) before tests were conducted. However, this information has not been made available to Biopraxis and therefore could not be included in this report.

Six catalysts were chosen from the modified production experiments; in addition, nine were chosen based on results from environmental remediation studies that indicated new and unusual catalysts had been developed.

Three pairs of catalysts were prepared from recipes in which catalysts are produced under oxygen,

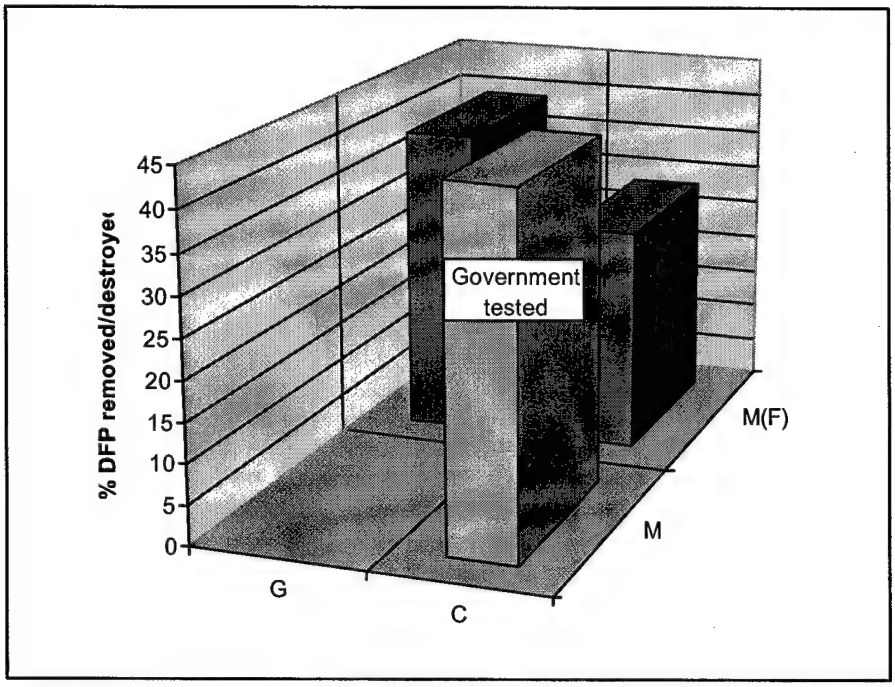

Figure 5: MMO01 vial tests against DFP

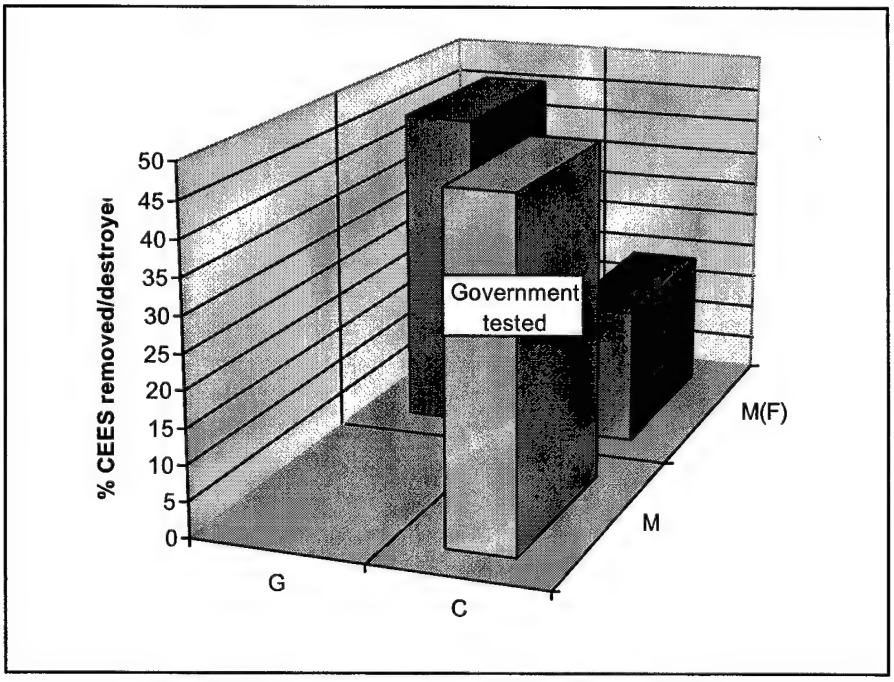

Figure 6: MMO01 vial tests against CEES

i.e., one that was sent to the Government previously and performed well, matched against one produced by a modified recipe that appeared to be more effective against simulants. These included:

- TMO01/MC and TMO01/MG

  TMO01/MC performed very well against GD and moderately well against HD in earlier Government penetration cell tests, and performed well against DFP in vial tests and penetration cell tests at Biopraxis. TMO01/MG exhibited greater efficacy against DFP and substantially great efficacy against CEES in recent vial tests.

- TFO01/FC and TFO01/FD

  TFO01/F_S performed very well against GD (81.3% reduction) and moderately well against HD (56.4% reduction) in earlier Government testing; and also performed well against DFP and CEES in earlier Biopraxis vial tests. TFO01/FD was substantially better at removing/degrading both DFP and CEES than TFO01/FD, which is a variation of the TFO01/F_S recipe.

- TFO01/F_S and TFO01/M_S

  As noted above, TFO01/F_S did very well in earlier Government tests. Studies on environmental remediation have found that substituting M for F can produce more reactive materiel.

Another nine catalysts were chosen on the basis of environmental remediation studies. As mentioned earlier, these studies identified some key production parameters that produced superior catalysts under nitrogen. Some of the catalysts that performed well in earlier Government tests were modified using these new recipes, which appeared to produce catalysts with interesting properties. Due to timing and funding constraints, the "new, improved" version(s), as well as a fresh batch of the original catalyst, were provided to USAMRICD without simulant testing. (Aliquots of each sample were retained at Biopraxis, and some limited DFP testing, as reported above, was done after the samples had been sent to the Government.) The catalysts that were provided included:

- MSR06/FL and MSR06/ML

  MSR06/FL performed extremely well in earlier Government tests (93.1% reduction of GD penetration, and 81.5% reduction of HD penetration.) Environmental remediation studies found that substituting M for F could produce a catalyst that is superior for other applications.

- MSR03/ML, MSR03/FL, and MSR03/MF

  MSR03/FL performed moderately well in earlier Government tests (65.3% reduction in GD penetration, and 53.2% reduction in HD penetration.) As noted above, substituting M for F can produce a catalyst that is superior for other applications. In addition, substituting F for L can produce very unusual catalysts.

- TSR02/MF and TSR02/ML

  TSR02/MF performed moderately well in earlier Government tests (56.5% reduction in GD penetration, and 52.6% reduction in HD penetration.) Substituting L for F can produce a catalyst that is superior for other applications.

- MSR05/FL and MSR05/ML

  MSR05/FL performed moderately well in earlier Government tests (51.8% reduction in GD penetration, and 53.8% reduction in HD penetration.) As noted above, substituting M for F can

produce a catalyst that is superior for other applications.

Two-liter samples of all of these catalysts were prepared and sent to the Government for testing with surety materiel.

Government Testing with Surety Materiel

As noted above, Government testing was cut short by the diversion of funds to support the war in Iraq. The two TFO01 series of catalysts were not tested at all. A single formulation of the other catalysts was tested against HD and/or GD in vapor penetration cells. The results were compared against Government ICD# 3004 (TSP) which had a time to breakthrough (1,000 ng) for HD of 586±87 minutes, and a total penetration at 20 h of 2758±299 ng HD; and a time to breakthrough (1,000 ng) for GD of 346±68 minutes, and a total penetration at 20 h of 6672±865 ng GD.

As above, it should be remembered that preparation and storage under air may adversely affect formulations containing catalysts prepared under nitrogen. Biopraxis has found that these catalysts are stable for years if kept under nitrogen; and a skin cream could be prepared and sealed into tubes under anoxic conditions. Information on formulation preparation and storage, and the length of time the formulation was stored prior to testing, was not provided to Biopraxis, and therefore could not be considered in the following analyses. Moreover, the methods used to prepare a given formulation (e.g., the percentage of each component, whether moist or freeze-dried catalyst was used, and the method used to mix all the components together) can have a significant impact on how well the formulation performs; a poorly mixed formulation may break through immediately even if the catalyst itself is highly effective against the agent. Accordingly, the results given below reflect the ***minimum*** performance that a given catalyst may yield.

- TMO01/MC and TMO01/MG:

  In earlier Government vapor penetration cell tests, TMO01/MC performed very well against GD (1182±148 minutes to breakthrough, a 342% increase over TSP, and 1081±444 total ng penetration in 20 h, a 84% reduction in comparison with TSP) and moderately well against HD (944±140 minutes to breakthrough, a 161% increase in over TSP, and 1601±329 ng penetration in 20 h, a 42% reduction in comparison with TSP).

  The formulation that was prepared this time was tested against GD and HD vapors again. It did even better, taking 4,642±2,389 minutes to breakthrough (an increase of 1,342% in comparison with TSP), and 124±121 total ng at 20 h (a reduction of 98%). It should be noted that the data from three of the five cells clustered together, with an average of 6,372 minutes to breakthrough (1,842% increase), and 36 ng penetration at 20 h (99.5% reduction), while the other two averaged 2,046 minutes and 256 ng, respectively. I.e., the catalyst would yield even better performance if the formulation were mixed/spread consistently.

  TMO01/MG exhibited greater efficacy against DFP and substantially great efficacy against CEES in vial tests. It was tested as a single formulation, against GD, by the Government. The results were excellent, i.e., 3,686 ±3,194 minutes to breakthrough, an increase of 1,065%; and 459±395 ng penetration in 20 h, a reduction of 93% in comparison with non-reactive TSP (I3004). Individual cell data were not provided; but the very large standard deviations indicate that several cells did far better than the average. The Government did not test the formulation against HD.

- MSR06/FL and MSR06/ML:

  In earlier Government tests, MSR06/FL performed extremely well (93.1% reduction of GD penetration, and 81.5% reduction of HD penetration.) The formulation that was prepared this time

was tested against GD and HD vapors again. Performance against GD was extraordinary; i.e., 57,096±44,512 minutes to breakthrough (16,502% increase) and 3±4 ng penetration at 20 h (99.96% reduction). Performance against HD was good; i.e., 1,269±477 minutes to breakthrough (217% increase) and 1,131±734 ng penetration by 20 h (59% reduction.)

Environmental remediation studies found that substituting M for F could produce a catalyst that is superior for other applications. MSR06/ML had been tested against DFP (after the catalyst was submitted to the Government), but was tested against HD only by the Government. It did well in comparison with I3004 (1,105±370 minutes to breakthrough, a 189% increase; and 1,183±663 ng penetration by 20 h, a 57% reduction), but not as well as hoped.

- MSR03/ML, MSR03/FL, and MSR03/MF:

MSR03/FL performed moderately well in earlier Government tests (65.3% reduction in GD penetration, and 53.2% reduction in HD penetration.) Substituting M for F can produce a catalyst that is superior for other applications. In addition, substituting F for L can produce very unusual catalysts. These catalysts were screened against DFP only, after samples had been sent to the Government for evaluation. MSR03/FL did very well against DFP; the others were not nearly as effective.

The Government spreadsheet reports having made formulations from five MSR03 catalysts, three of which were given codes that do not match the codes provided to the Government. It is therefore difficult to determine which catalysts were actually tested as formulations and how their performance matched expectations.

Apparently, MSR03/FL was not tested against surety materiel.

MSR03/ML was apparently tested against HD only. It did well in comparison with I3004; i.e., 1,411±349 minutes to breakthrough (241% increase) and 619±108 ng penetration by 20 h (78% reduction.)

"MSR03/MLA" was screened against both HD and GD. It did very well against GD; time to breakthrough was 2,055±688 minutes (594% increase) and total penetration by 20 h was 222±85 ng (97% reduction.) This formulation also yielded the best performance against HD of those tested on this program; i.e., time to breakthrough of 1,571±98 minutes (268% increase) and total penetration at 20 h or 598±70 (78% reduction.)

"MSR03/MX" and "MSR03//MLB" were screened against HD. "MSR03/MX" did well, increasing the time to breakthrough by 201% (1,179±94 minutes) and reducing total penetration at 20 h by 63% (1,029±176 ng), which was better than MSR03/FL in the earlier Government tests, although not as well as some other catalysts that were studied on this program. "MSR03//MLB" exhibited a similar efficacy against HD, increasing time to breakthrough by 188% (1,101±80) and reducing penetration by 57% (1,198±158 ng.)

- TSR02/MF and TSR02/ML:

TSR02/MF performed moderately well in earlier Government tests (56.5% reduction in GD penetration, and 52.6% reduction in HD penetration.) The new formulation made with this catalyst was tested against HD only. It exhibited a similar efficacy this time, increasing time to breakthrough by 197% (1,154±104 minutes) and reducing penetration at 20 h by 60% (1,095±204 ng.)

Substituting L for F can produce a catalyst that is superior for other applications. Due to time and funding constraints, TSR02/ML was not tested against simulants. The Government spreadsheet

does not show a TSR02/ML but does list a "TSR02/MC", which is presumably a typographical error. This catalyst was screened against HD, and its performance was very similar to that of TSR02/MF; i.e., it increased time to breakthrough by 203% (1,187±118 minutes) and reduced penetration by 62% (1,035±217 ng.)

- MSR05/FL and MSR05/ML:

  MSR05/FL performed moderately well in earlier tests (51.8% reduction in GD penetration, and 53.8% reduction in HD penetration.) It was not tested by the Government on this program.

  As noted above, substituting M for F can produce a catalyst that is superior for other applications. MSR05/ML was screened against both GD and HD. It increased the time to breakthrough for GD by 531% (1,836±1,212 minutes) in comparison with I3004 and reduced penetration by 94% (412±445 ng.) It also the time to breakthrough for HD by 201% (1,175±325 minutes) in comparison with I3004 and reduced penetration by 57% (1,175±594 ng.) I.e., the new catalyst recipe significantly improved performance against GD, while retaining its efficacy against HD.

In short, all of the formulations tested against surety materiel by the Government had substantially improved efficacy against GD and/or HD, in comparison with the non-reactive TSP. Some were extraordinary; e.g., MSR06/FL, which did not allow any detectable GD penetration for 20 h and was projected to take more than 950 hours (40 days) to reach breakthrough. This same formulation also showed excellent efficacy against HD.

It should be noted that, since these catalysts are solid particulates, catalysts with different chemistries do not interact with each other. Therefore, a mixture of different catalysts may be used to produce a superior skin cream formulation. Environmental remediation and earlier rTSP studies showed that the results obtained with mixtures were often synergistic rather than additive; i.e., were much more effective than might be predicted on the basis of single-catalyst tests.

KEY RESEARCH ACCOMPLISHMENTS

- Catalyst production parameters that were shown to improve performance against pollutants on environmental remediation programs were explored for their ability to improve performance against CW agents. As far as can be determined from the limited testing that was done, catalyst performance can be predicted on the basis of simulant testing, and can be improved by "tweaking" the catalyst production parameters.

- Fifteen catalysts were prepared for Government surety materiel testing. All of the formulations that were screened showed substantially superior performance against GD and/or HD, in comparison with the non-reactive TSP.

- The most effective formulation against GD, made with MSR06/FL catalyst, did not allow any detectable GD penetration for 20 h and was projected to take more than 950 hours (40 days) to reach breakthrough. This same formulation also showed excellent efficacy against HD.

- The most effective formulation against HD, made with "MSR03/MLA" catalyst, increased the time to breakthrough by 268%, in comparison with the non-reactive TSP (i.e., did not reach breakthrough for more than 26 h), and reduced penetration by 78% (i.e., allowed only 598 ng to penetrate in 20 h.) It also did very well against GD; time to breakthrough was increased by 594% to more than 34 h, and total penetration was reduced by 97% to only 222 ng in 20 h.

REPORTABLE OUTCOMES

- 'Microcatalysts as Active Moieties for Topical Skin Protectants,' Ann E. Grow, Biopraxis, Inc., and Ernest H. Braue, Jr., USAMRICD, presented at the U.S. Army Medical Research and Materiel Command (USAMRMC) *Bioscience 2002 Medical Defense Review.*

- Funding for the rTSP development program area was halted in order conserve Government monies for the war in Iraq.

CONCLUSIONS

The concept of applying a topical protectant to vulnerable skin surfaces before entry into a chemical combat arena has been proposed as a means of protecting troops from percutaneous chemical warfare agent toxicity since these weapons were first used during World War I. Topical protectants would augment the protection afforded by the protective overgarments or, ideally, redefine the circumstances requiring Mission Oriented Protective Posture (MOPP) levels. The rapid action of vesicating agents such as sulfur mustard and lewisite suggests that a preexposure skin protection system, or a contamination avoidance approach, offers the best opportunity to prevent the serious consequences of the percutaneous toxicity of blistering agents. A skin protectant also reduces the risk of exposure to organophosphorus agents which, unlike vesicants, are lethal in droplet amounts. In addition, the development of improved prophylactics for CW agents can deter their use by the enemy, and increase the warfighter's capability to sustain his operational tempo.

The U.S. Army Chemical School has developed a topical skin protectant (TSP) against CW agents (now called "SERPACWA") that extends the protection afforded by MOPP and allows a longer window for decontamination. However, since it is a non-reactive barrier cream, it does not completely remove the possibility for contamination and, therefore, decontamination is still required. In addition, it does not provide very good protection against mustard vapor. In order to overcome these deficiencies, there is a clear need for a next generation TSP that contains a reactive component that will decontaminate CW agents as well as protect against nerve and mustard vapors.

The work that has been done to date has been extremely successful. Vial screening tests identified many, diverse catalysts that showed efficacy against DFP and/or CEES. Catalyst production parameters that can be "tweaked" to improve performance have been identified. Government formulation testing against surety materiel has identified many catalysts that exhibit excellent efficacy against GD and/or HD. Several methods can be used to enhance performance even further, notably the use of catalyst mixtures and optimizing the composition of the formulation. Many promising, new catalysts remain to be screened. Since the precursors are inexpensive and the simple production method offers a high yield under ambient conditions, the costs for producing the catalysts in bulk are expected to be very low.